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Ostermeier, Christian; Prenzel, Manfred; Duit, Reinders

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Christian Ostermeier, Manfred Prenzel and Reinders Duit

IPN - Leibniz-Institute for Science Education, Kiel, Germany

Corresponding Author:

Christian Ostermeier
IPN – Leibniz Institute for Science Education
Olshausestr. 62
D 24098 Kiel, Germany
ostermeier@ipn.uni-kiel.de

Improving Science and Mathematics Instruction -

The SINUS-Project as an Example for Reform as Teacher Professional Development

Abstract

This article presents an example of teacher professional development based on a perspective of situated learning and implemented on a large scale. We consider teacher professional development from three perspectives. First, teacher professional development is a key factor in improving classroom instruction. Second, teacher professional development is a vehicle for conveying knowledge from research into classrooms. Third, teacher professional development is an object of research itself. A German project to improve science and mathematics teaching (SINUS) – comprising 180 schools in a pilot-phase and more than 1,700 schools in a second phase of scaling-up – serves as an example of this framework for teacher professional development. Using these three views we describe the foundations of the programme and provide a brief account of the programme's background and its conception. We show how the central elements of the programme (11 modules) are based on an in-depth analysis of science and mathematics education, as well as how those modules structure the professional development of the teachers. Finally, we provide an overview of the evaluation of the programme. A large-scale comparison between SINUS schools and a representative sample of German schools tested in PISA 2003 showed positive effects of the programme with regard to students' interest and motivation as well as competencies in science and mathematics. In the light of these findings, we argue that teachers' learning related to daily pedagogical challenges in the classroom should be central to all professional development initiatives.

Introduction

Teacher professional development is often discussed as one of the key factors in improving educational systems. Teachers constitute the key group of professionals acting in educational systems. In the following we will consider teacher professional development from three perspectives.

First, teacher professional development plays a crucial role in improving classroom instruction. Teachers are directly involved in designing learning environments for their students. They provide learning opportunities for their students, and thus have a major impact on learning processes and outcomes. Obviously, teachers are the pivotal target group when it comes to improving the quality of schools, instruction, learning and understanding. In this respect the professional development of teachers should be related to professional standards (National Council of Teachers of Mathematics (NCTM), 1991; Oser, 1997). Besides these more or less normal demands, professional development could also foster teachers' competence to deal with and to solve educational problems in classrooms and schools.

Secondly, professional development can serve as a vehicle to convey research-based educational knowledge into classrooms. It must be emphasized that there is no simple and direct way to transfer findings and insights from research on learning, instruction and science and mathematics education into principles for acting in the classroom. Educational research provides background knowledge and tools for instruction. Educational research helps to identify problem areas of learning, teaching and schooling that could serve as a frame for professional development. Additionally, educational research can offer empirically-founded theories as scaffolds when teachers are tackling typical problems of their profession (Hiebert, Gallimore, & Stigler, 2002).

From a third perspective, teacher professional development itself is an important and interesting object of educational research. More or less obvious are the questions of how professional development programmes for teachers are designed, how they can be implemented, and what impact they have on the participating teachers as well as on their classrooms, schools, and students. Besides the research on aspects of implementation and evaluation studies, the effects of professional development on teacher expertise is of special relevance (Garet, Porter, Desimone, Birman, & Yoon, 2001; van Driel, Beijaard, & Verloop, 2001).

In the following these three views of teacher professional development will be discussed in more detail. The different perspectives played a decisive role in the design of a recent professional development programme in the field of mathematics and science instruction. The aim of the programme was to improve the quality of mathematics and science education in Germany as a reaction to the findings of TIMSS and PISA. As this programme – called the SINUS project - has been enlarged during recent years from a pilot study (including 180 schools) to an extensive programme involving over 1,700 schools, it may serve as an example of a comprehensive attempt to improve the quality of education by means of teacher professional development. To classify the approach, two general directions of professional development can be discerned.

On the one hand, we find professional development programmes offered by institutes responsible for in-service teacher training. These institutionalized programmes comprise more or less conventional approaches to professional development and normally characterize the situation in many countries, including the U.S. or Germany (Sykes, 1996). This approach to professional development often attempts to transmit knowledge and skills by providing isolated training seminars dedicated to a specific topic. Often this kind of teacher professional development is regarded as less effective because it does not take into account the daily problems of classroom instruction.

On the other hand, there are professional development initiatives (among them the projects described in the articles of this special issue) that are related to educational reform (Beeth & Rissing, 2004; Krainer, 2005; Sykes, 1996; Tytler, 2007). These professional development programmes are often designed from a perspective of situated learning (Borko, 2004; Borko *et al.*, 2000; Putnam & Borko, 2000) and aim to relate teacher learning to the daily tasks of classroom instruction. The quality development programme that will be outlined in the following is best classified as an example of this second approach as well.

Improving the Quality of Science and Mathematics Instruction: A Professional Development Programme

As an example of a programme for professional development that has been designed from a perspective of situated learning and that relates to reform as a problem-oriented change process to improve science and mathematics teaching, we will describe one approach taken in Germany in more detail. We discuss the programme using the three perspectives mentioned in the beginning:

First, professional development is considered a key factor for improving classroom instruction. In this section we will outline the foundations of the programme, give a brief account of the programme's background and its conception, discuss the role of teachers in the programme and illustrate how professional development is facilitated in the programme. Also we will highlight the educational context in which the professional development programme takes place.

Second, professional development is discussed as a vehicle for conveying knowledge from research into classrooms. We will outline how research-based knowledge contributed to the conception of the programme. We will show how the central elements of the programme, the eleven modules, are based on an in-depth analysis of science and mathematics education research, as well as how those modules structure the teacher professional development.

Third, professional development is regarded as an object of research itself. In this section we will provide an overview of the evaluation of the programme and of instruments that were used to assess the effects of the programme. We will address the following five questions: (1) Are the schools in the programme 'normal' schools? (Control of selection effects), (2) How did the teachers engage in the programme? (Acceptance studies), (3) What kind of support do teachers want? (Research on conditions for implementation), (4) What products and understandings did the teachers develop? (Analyses of products and processes) and (5) What did the students learn? (Studies of the effectiveness of the programme).

Professional Development as a key to promote Quality Development

In this section, we give a structured overview of the programme. We will refer to four key elements of professional development suggested by Borko (2004): (a) The professional development programme; (b) the teachers, who are the learners in the system; (c) the facilitators, who guide teachers as they construct new knowledge and practices; and (d) the context in which the professional development occurs.

Thus, in the following we will present the background and basic conception of the programme, discuss the specific and central role teachers play in the programme, give an overview of the support structure and the people involved in facilitating the professional development of the teachers, and describe the specific educational context in which the programme takes place.

(a) The professional development programme: SINUS

Before describing the approach to professional development in the following section, we briefly describe the background of the programme. The responsibility for school teaching in Germany, as, for example, in the United States of America, lies within the administrative authority of each of the federal states ('Länder'). The Third International Mathematics and Science Study (TIMSS) (Beaton *et al.*, 1996a; Beaton *et al.*, 1996b) and German students' mediocre performance strongly aroused public interest. An effort to tackle the problematic findings was considered necessary.

Thus, the German federal government, in cooperation with the federal states, commissioned a group of experts to develop a framework in preparation for the set-up of a programme to increase the efficiency of mathematics and science instruction (Bund-Länder-Kommission für Bildungsplanung und Forschungsförderung, 1997). The programme conception was based upon an analysis of problem areas of German mathematics and science teaching (Baumert, Bos, & Lehmann, 1998; Baumert et al., 1997; Bund-Länder-Kommission für Bildungsplanung und Forschungsförderung, 1997). The major goal of the programme is to improve classroom instruction in mathematics and science and, in doing so, to foster student learning and understanding, as well as motivation and interest in those domains. There are four central characteristics of the programme aimed at achieving those goals.

First, the programme refers to central problem areas in German mathematics and science teaching as pointed out, for example. by the TIMSS 1995 Video Study (Stigler & Hiebert, 1997). The problem areas are conceptualized into 11 modules that provide a framework for improving classroom instruction (Table 1). Schools in the programme had to choose at least two modules to work on. Modules are not preformed teaching units or whole science or math programmes. Rather, they outline central aspects of the problem area and provide examples of how to overcome the identified shortcomings. Modules serve as a starting point and frame to improve teaching. They also help to categorize the documentation of processes and products (developed units, materials, etc.) and provide a shared language to facilitate communication about science and mathematics teaching. The choice of a system of modules also makes professional development adjustable to the specific local situation and problems at the participating schools.

INSERT TABLE 1 ABOUT HERE

Second, the programme introduces processes of quality development at the level of the participating schools. The teachers are encouraged to set their specific working goals, to develop new materials or modify existing approaches, and engage in self-evaluation methods that are easily applied to their classroom teaching. To ensure steady and sustainable improvement, teachers first are sensitized to typical problems in mathematics and science teaching. A culture of feedback is considered crucial in order to detect problems in the future and work on them. The programme seeks to draw upon the collective wisdom inherent in the communities of colleagues. In the long run, an enduring system to ensure the quality of teaching should develop at the school level.

Third, the programme's leading principle is cooperation and collaboration on different levels, especially between the teachers participating in the programme. In German schools, cooperation is rather uncommon (Terhart, 1987). Nonetheless, according to school effectiveness research, collaboration among teachers constitutes a main characteristic of effective schools (Sammons, 1999; Scheerens & Bosker, 1997). Also professional development initiatives prove to have the greatest effect if a group of colleagues from one school is engaged in the activities (Garet et al., 2001).

Fourth, the teachers' work is supplemented by support from science and mathematics educators and through research on learning and instruction. Teachers working on modules have access to scientifically-based materials and worked-out examples referring to the modules. There are also various possibilities for consultation and in-service training offered within the programme.

(b) Teachers as the learners in the system

Teachers are the one group of professionals who have immediate influence to improve learning environments in classrooms. Therefore, the best chance to increase student competencies and motivation is to devote a programme to the professional competencies of in-service teachers.

Different forms of teacher involvement exist in the programme. The basic level of involvement is the cooperative work of science and/or mathematics teachers at a particular school. That is, the smallest unit of cooperation is the subject department. This can be the physics, biology, chemistry or the mathematics department (or some combination, if two, three or four departments take part). In addition to cooperating at the school level, teachers work together across school boundaries. To foster this level of cooperation, the programme schools are organized into small school networks (school sets) of six schools each.

Teachers in the programme are seen as the experts in teaching and learning who are capable and responsible for further developing and improving their own classroom teaching. In order to do so, they have an array of problem areas (modules) with which they can frame their work, and they share their thoughts and ideas with their colleagues. The teachers, who are the learners in the programme, are seen as reflective practitioners (Schoen, 1987) who work in a self-directed and cooperative way.

(c) The facilitators, who guide teachers as they construct new knowledge and practices

The cooperative work of the teachers is supported on different levels. In each school, there is one person coordinating the programme activities at the school level. In addition, the schools are organized in small school networks. Each school network has at least one coordinator who gives technical support and guides and structures the classroom-related work of the teachers. Besides the coordination of the school networks, several support structures are located at the level of the participating federal states. Local district authorities and education ministries, as well as the states' in-service training institutes, serve as valuable assets for the infrastructure of the programme. Additionally, the people in charge of the programme in each state are encouraged to cooperate closely with faculty and staff of local universities and to utilize the knowledge and experience of science and mathematics educators and researchers studying learning and instruction.

As a result, staff responsible for teacher training are familiarized with the approach to professional development suggested by the programme – that is, teachers improving their own classroom teaching in a collaborative way over a longer period of time within a conceptual framework related to problem areas (modules) of science and mathematics teaching. Thereby the existing institutions of teacher training will experience a steady influence in the direction of a long-term and school-based professional development approach designed from a perspective of situated learning.

(d) The context in which the professional development occurs

The TIMS-study (Baumert et al., 1997; Beaton et al., 1996a; Beaton et al., 1996b) gained a high level of interest in German public discussion. This has been the most important reason for developing the programme SINUS. However, the professional development programme occurs in a special educational context that is characterized by following aspects:

- The general appreciation of mathematics and science and corresponding school subjects – or even school and education in general – is rather low in Germany. Often success and failure in mathematics and science subjects is only attributed to ability. Thus, efforts to improve one's competencies appear not to be worthwhile from the students' point of view.
- There is a high degree of individualism of teachers in German schools (Terhart, 2000). Most commonly the teacher is a "lone warrior" who almost never opens her or his classroom door in order to share teaching experiences with colleagues.
- There are almost no incentives to engage in professional development. Schools and districts do not have systematic requirements to participate in in-service-training. However, some federal states have started to make in-service professional training compulsory.
- Existing support systems tend to offer in-service-training without taking much account of teachers' needs. Professional development is seldom oriented towards the actual demands of teachers. Often "one-shot training" is offered that is not part of a coherent curriculum. Additionally, universities do not play a substantial role in teacher professional development.

In conclusion, there is a high level of need for professional development that takes into account the demands of daily classroom teaching and support systems that are demand-oriented. Instead of stand-alone training, in-service-training should be embedded into a classroom-related professional development structure that focuses on continuous development. The professional development approach outlined above takes those aspects very seriously and adheres to them in multiple ways.

Professional Development as a Vehicle to convey Knowledge from Research into Classrooms

The starting point for the teachers' work is the set of 11 modules. Findings from research on learning and instruction, educational psychology, and science and mathematics education are the foundations of the modules. Science and mathematics educators are engaged to support the professional development on various levels. The modules are a frame of reference for support. Within the frame of the modules, written materials, in-service training or consultation is offered to the teachers developing their own classroom instruction. In the following we choose module 2 “Scientific inquiry and experiments” in order to (1) demonstrate how scientifically-based knowledge is introduced into the modules and to (2) show the ways teachers are introduced to the basic ideas of the modules.

(1) The foundation of each of the modules is a thorough analysis of the current state of the art of research in science and mathematics education and research on learning and instruction in general (Seidel & Shavelson, in press). Module 2 “Scientific inquiry and experiments” takes up the current academic discussion of scientific work and experiments and their effect in science classrooms (Seidel & Prenzel, 2006). The use of scientific inquiry and experiments in classroom learning has been studied thoroughly in science education. For instance, White and Frederiksen (1998) showed that students learning with an inquiry approach improved significantly on physics as well as inquiry assessments. Furthermore, positive effects on students’ attitude towards science could be observed (George & Kaplan, 1998). However, studies focussing on the role of student experiments do not yield such a clear picture. The mere implementation of student experiments does not seem to have a positive impact. Rather, the way in which experiments are embedded in classroom instruction and the way in which science is represented by inquiry and scientific investigations seems to be more crucial to student learning and attitudes (Harlen, 1999). In order to integrate experiments and scientific investigation and inquiry in classrooms with the goal of enhancing student thinking and deeper understanding, some principles can be drawn from research in science education (Harlen, 1999; Hofstein & Lunetta, 2004; White & Frederiksen, 1998):

- Experiments should be both challenging and thought-provoking. They also should stimulate students’ interests.
- The students need to have a clear picture about the intention of the experiment.
- The main objective for employing student experiments is learning and deeper understanding. Students have to deal with an idea and not just act upon or handle scientific equipment.
- Students need to be given the choice to plan and interpret their own experiments.
- Experiments should support students to work in a self-directed manner.
- Scientific inquiry and experiments should bring about experiences of competence for students.

(2) There are several ways in which teachers are introduced to the basic ideas of the modules. Typically the group of teachers at a participating school chooses at least two to three modules to work on. The teachers are not directly exposed to the research basis of modules. Rather, they can access an array of module-specific support measures like basic written module descriptions, module-related classroom material and in-service training-workshops.

A first way to get acquainted with the idea of the module is through a basic written module description. These papers include a very brief introduction to the problem area and its empirical foundation. A description of possible shortcomings concerning the module is typically followed by specific examples of how to overcome those problems in classroom instruction. In module 2, for example, teachers are introduced to the principles concerning the use of experiments mentioned above and get exemplary experiments which they can try out in class and then exchange experiences with colleagues from their subject departments.

Besides the basic module descriptions, there is of course a vast amount of module-related reform-oriented material available to the teachers. There are many good examples provided especially by science and mathematics educators from universities and teacher-training institutes. The internet server of the programme plays a crucial role in managing and providing this module-related information.

Another important way to introduce teachers to the basic content of the modules is through in-service training sessions. These sessions typically start with a brief introduction to the module-specific ideas and their research base. A main focus, however, is to offer innovative module-related examples that can be applied to classroom instruction. The basic idea is that teachers try out new examples – often after adapting them to the specific classroom situation they are confronted with – and share the experiences with the group of colleagues at the school or school network level.

In summary, modules serve as a frame of reference for teacher professional development and support. They are based on current research on learning and instruction, especially in the domains of science and mathematics education. Science and mathematics educators, as experts on module-related topics, are engaged to support the teachers' work. As a result, a network of support is being built throughout the country. Through the set of modules, research-based knowledge can find its way into real classrooms. However, the route is not a direct one. An important characteristic of the kind of professional development in the SINUS programme is that it is oriented towards key problem areas. The teachers can locate their own crucial classroom-related problems within the frame of the modules and are then supplied with examples to help solve those problems.

Professional Development as an Object of Research:
Evaluation of the SINUS-Programme

In this section, we present an overview of the research accompanying the professional development programme. We used different approaches for evaluation. We will refer not only to findings from these evaluations, but also to some reports of teachers' experiences with the programme that help to complete the picture.

In the following, we present a more problem-oriented overview of the findings of the research linked to the professional development programme. We will try to answer some questions that may be critical for the evaluation of the programme:

- *Are the schools in the programme 'normal' schools? (Control of selection effects).* This question refers to the control of possible selection or sampling effects.

- *How did the teachers engage with the programme? (Acceptance studies).* The second question deals with the acceptance of the programme by the teachers. Acceptance is a necessary condition for success. We are also interested to learn the extent of teachers' agreement with the programme's philosophy and how they translate the programme into practice.

- *What kind of support do teachers want? (Research on conditions for implementation).* Most interesting for the management of the programme is information about conditions that foster or hamper the realization of important principles of the programme. For example we looked at the support the teachers wanted.

- *What products and understandings did the teachers develop? (Analyses of products and processes).* The success of the programme finally depends on the output. In this respect we looked at the materials the teachers developed themselves. Finally, an important aspect of investigation is the effects on the students.

- *What did the students learn? (Studies on the effectiveness of the programme).* This question deals with the major goal of the professional development programme: to increase student competencies and motivation in science and mathematics.

In the following we refer to these questions in describing the purpose of the investigation, the design of the study and methods used as well as the results. We end by drawing conclusions about each of the questions.

(a) Are the schools in the programme 'normal' schools? (Control of selection effects)

Purpose of investigation. Our first aim was to check the sample of schools. Professional development programmes may attract schools and teachers who are already more engaged in innovation than others. In order to disseminate the programme conception to a wider range of schools, it is important to rule out the hypothesis that the approach only worked because of more favourable conditions at the programme schools. Thus, we wanted to investigate whether the participating schools were a special sample with regard to classroom- and school-related preconditions. Relevant conditions refer to mathematics- and science-specific cognitive and motivational student variables at the school level, as well as more general student ratings about the school (e. g. school climate).

Design of study. 171 programme schools were tested in a first study in 2000 to answer these questions. The instruments were selected from our national extensions of the PISA study so that a comparison of SINUS-schools to a representative sample of German schools (PISA/E 2000 - an extended PISA-sample) could be made.

Results. Our data show no meaningful differences between the PISA sample and the programme schools in the first assessment (year 2000) (Ostermeier, Carstensen, Prenzel, & Geiser, 2004). The schools did not differ with respect to resources, staff, programmes, experiences with innovations and school climate. Also we found comparable levels of interest, motivation and self-concept. Most importantly the programme schools did not systematically show a higher or a lower performance on the mathematics and science assessments.

Conclusions. Overall, the programme schools did not differ systematically compared to a nationally representative school sample. This result is an important prerequisite for the dissemination of the programme approach. It is more likely to successfully disseminate an approach tested in “normal” schools, whereas it would seem almost impossible to do this with an innovation tested only in the most excellent schools. In addition, the data from the first study will serve as a baseline for the investigation of changes in student competencies and interests towards the end of the programme.

(b) How did the teachers engage in the programme? (Acceptance studies)

Purpose of investigation. The programme has been conceptualized by integrating research findings on school innovation and reform showing that changes of professional actions are most likely to occur when they are accepted by the main actors, the teachers. Also new approaches will work successfully not only if they are accepted, but when they become part of the professionals' routines (Anderson & Helms, 1999; Brown, 1997; Knapp, 1997; Stake, Burke, Flôres, Whiteaker, & Irizarry, 1997). Therefore, one goal was to study the extent to which the programme and its features are accepted by the target group, the teachers. Information on the acceptance level helps adjust the programme to the needs of the teachers and schools. So the acceptance study serves as formative evaluation.

Design of the study. Questionnaires were designed containing questions about the degree to which the teachers accept the programme and its goals. Specifically, items were designed to study how engaged the teachers are in the cooperative quality development, how the teachers accept the cooperation, how content they are with programme activities, and how they perceive the development of their professional competencies throughout the programme. The teachers were also asked to assess the quality of the support provided as well as to give an account of their actual use of this assistance.

Two surveys were conducted during the pilot phase of the programme. In 2000, a total of 557 teachers, and in 2002, 527 teachers completed the questionnaire. Because of data protection regulations, data from the two points of measurement could not be linked on an individual level. However, data from both times can be compared using data aggregated at the school level (Table 2). Although the participating teachers were the main target group of the studies of acceptance, we additionally included other groups in our study, namely the principals of the schools, the coordinators, as well as small samples of parents and students from the schools.

Results. The results of both surveys suggest that participating teachers engage in programme activities to a high degree. In general, teachers invest a lot of time in cooperative quality development. The additional time spent on programme-related activities exceeds the amount of reduction of teaching load to a significant degree.

Teachers report exchanging programme-related materials, cooperative clarification of goals, working together on modules, cooperatively reflecting on teaching, and receiving as well as providing feedback on cooperatively-developed materials. Naturally, the frequency of those activities is higher at the level of the schools. Cooperation at the level of the school networks takes place less often but is still remarkably high, bearing in mind the considerable effort needed to get together at this level.

In addition to the frequencies of cooperative quality development activities, we wanted to obtain indicators of how the teachers accept the cooperation within the programme, about how content they are with programme activities and about how they perceive developments throughout the programme. As a next step, we looked at how the teachers' ratings developed throughout the course of the pilot programme. Table 2 shows results for those three aspects for the two points of measurement: the surveys in 2000 (N = 557 teacher responses) and in 2002 (N = 527) (Ostermeier, 2004). For comparison of the two points of time, data have been aggregated at the school level (scales with response categories from 'I strongly disagree' = 1 to 'strongly agree' = 4).

- *Teachers' acceptance of cooperation.* Three aspects regarding cooperation in the professional development programme have been assessed (Table 2). Each aspect has been operationalized by a scale comprising three to seven items, with the first one referring to what degree teachers experience cooperation as being effective. The second scale includes items that assess to what extent the participants experience a gain for their professional work through cooperation. The last aspect deals with issues that could foster or hamper cooperation and is labelled "Unhampered cooperation". As Table 2 shows, teachers rate all three aspects rather positively. The ratings even increase in the second survey.
- *Teachers' contentedness with programme activities.* The next step was to study how content the teachers are with different aspects of the programme. For example, items referred to collaboratively developing and testing new approaches in classroom instruction (scale labelled "Appreciation of cooperative quality development") or getting new ideas for future classroom instruction. Two further scales related to the amount of additional work load through programme activities and the support and consultation provided by coordination on different levels. As in the ratings referring to the assessment of cooperation, teachers' answers were positive. Except for one scale ("Support and consultation"), the already positive ratings increase significantly in the second survey.
- *Teachers' perceived development throughout the programme.* We also wanted to investigate which changes the teachers experience throughout the course of the programme. More precisely, teachers were asked to rate how they perceive the

development of their own professional competencies, how they perceive improvement with respect to classroom instruction, and how they perceive the support and approval of programme activities from parents and colleagues not participating in the project. Again, ratings are significantly higher at the second measurement point. As in the two former areas, ratings are also very positive. However, there is one exception in this positive appraisal. Participating teachers rate the approval and acceptance of the programme expressed by non-participating colleagues and parents rather low. Although those ratings are significantly higher in 2002, they are still below the theoretical mean (2.5) of the scale.

INSERT TABLE 2 ABOUT HERE

Conclusions. In general, findings indicate engaged teachers. The acceptance of the professional development programme seems to be high. Also acceptance does not decrease over the course of the pilot phase.

However, an important group to work on seem to be parents and colleagues who are not or not yet involved in programme activities. Those groups form a proximal environment for the programme that might be crucial as an important supportive characteristic that may accelerate or hamper the professional development at the local level.

(c) What kind of support do teachers want? (Research on conditions for implementation)

Purpose of investigation. Information from the acceptance questionnaires can be interpreted as information on conditions for successful implementation of the programme. An important question in this respect is, for example, how teachers use and appreciate the offered support: What kind of support do teachers prefer or request? We also used the teacher questionnaires to ask some questions which could help us to identify conditions of a successful implementation of the programme. So we were interested to learn which conditions support or hamper the implementation of the central principles of the programme.

Design of the study. We also used the studies on acceptance in 2000 and 2002 to get feedback from teachers to optimize the support and for further guidance of the programme. Thus, in the questionnaires, teachers were asked to rate the extent to which they would need more of the following aspects: autonomy for programme work, supply of written materials, training meetings, possibilities of mutual exchange, precise instructions, and a precise determination of the goals for the programme work at the school (Ostermeier & Prenzel, 2005).

Results. The requests for support do not point in a specific direction. Nearly one half of the teachers want more support concerning each item, whereas the other half long for less. The data structure seemed suitable for running a Latent Class Analysis, looking for different patterns or types of requests. With LCA we could identify three groups of teachers. Two groups had in common that teachers wanted to get more material and wished for more precise instructions and a precise determination of the goals for the programme. The third group emphasized the need for mutual exchange, whereas the level of request for materials or precise instructions and goal determination was rather low. This group of teachers seems to be in line with the philosophy of the programme. They request ideas and suggestions, but they want to explore new approaches by themselves (Ostermeier & Prenzel, 2005).

We also found important differences between these request-groups concerning the use of support, the time spent on programme activities, and the perception of local coordination. The third group of teachers seems to use the support offered to a higher degree and to spend more time on programme activities. Those teachers also rate the local coordination more positively (Ostermeier & Prenzel, 2005). In 2002, similar groups could be identified by LCA. The third group of teachers thereby increased in size (Prenzel & Ostermeier, 2006).

Conclusion. The results indicate that a key feature is the coordination at all levels (school, set, state). The request types especially show that coordination on the level of the federal states, as well as the coordination of the small school networks, is crucial. There are different coordination approaches in the federal states that seem to have an impact on the way teachers engage in the programme.

The different teacher groups seem to need different support and treatment in the programme. So we drew the attention of the coordinators to different styles of engagement and needs and sensitized the facilitators to carefully take account of these differences.

(d) What products and understandings did the teachers develop?

(Analyses of products and processes)

Effects of modules. We refer to effects of the framework supplied by the modules and to teachers' experiences with the programme. We also report an example with regard to what products the teachers developed.

Experiences in the pilot phase. Very interesting effects of the modules find expression in visible products. They can be found on the internet server of the programme – both the internal and external sites – but also in a large number of publications.

These products include the outlines, worked-out examples, and materials, which have been provided by the scientific managers of the programme. In addition, there are a large number of materials, teaching units, classroom projects, curricula, and collections of tasks that have been developed by the teacher groups in the schools. For example, a group of teachers working on Module 2 "Scientific inquiry and experiments" developed a learning setting where students approach chemical phenomena by observing experiments in groups of three or four. Students are asked to describe their observations and think aloud about their ideas. The purpose of this setting is mainly to stimulate the students' pre-knowledge structures and to make their basic scientific ideas transparent so that further learning can be linked to them. The students' classroom interactions were videotaped and published on a CD along with comments that can be used to stimulate other teachers working on module two (Stamme & Stäudel, 2000).

With the support of local and central coordinators, a large portion of these materials is presented in a systematic module-specific way. A lot of these materials can be downloaded from the central internet server of the programme, as well as from the regional programme web pages of the participating federal states. The internet server is frequently used to gather information and to download module-related materials (Strecker, 1999). Also a huge amount of module-related approaches have found their way into written publications (Hertrampf, 2003). In the two phases of scaling-up (2003-2007) we used the portfolio-method to support and evaluate teacher professional development (Barton & Collins, 1993; Craig, 2003; Tucker, Stronge, Gareis, & Beers, 2003). We designed a tool (subject department portfolio) that requires teachers of one school to collaboratively document and reflect on efforts to improve their teaching and to make their thoughts and developments accessible to others (Meentzen, Ostermeier, & Prenzel, 2006). About half the schools were randomly chosen and asked to send in copies of their portfolio. The analyses of those portfolios promise to produce valuable insights into the products the teachers developed and the learning processes the teachers went through. Due to the vast amount of qualitative data results will be available after the scaling-up-project ended in 2007.

Conclusions. The experience in the programme indicates that a necessary condition for a professional development programme is to bring teachers into a situation where they have to invent new approaches very early. Therefore, we consider it crucial that they invent these new approaches in a very carefully-defined framework (modules), so that the chance that they might fail with new approaches is reduced to a minimum and the chance to experience success is increased. In this respect, the modules show very concrete ways to improve instruction step-by-step, and they increase the probability that changes can be integrated in teachers' routines.

(e) What did the students learn? (Studies on the effectiveness of the programme)

Purpose of investigation. Besides the above-mentioned aspects of formative evaluation, we asked how we could study the effectiveness of the pilot programme (in the sense of a summative evaluation). It is an important but rather complicated issue to design the evaluation of a pilot programme in the field where 180 schools and around 1000 teachers are participating.

Design of the study. The programme schools were assessed with PISA instruments again in 2003 (N=144 schools). As in 2000, we drew test items from the national extension of PISA 2003. Instruments assess the students' mathematics and science competencies and their motivation. Thus, the design allows us to evaluate the progress, at the school and programme level, in the students' mathematics and science performance and interest, as compared to a national sample of schools not participating in the programme. Additional school and teacher questionnaires provide information on teacher cooperation, school programme and evaluation policies.

Results. The results of the 2003 comparison of SINUS and PISA-schools indicate that SINUS showed positive effects in all areas investigated. The teachers in SINUS schools report more cooperation activities at the school level. Students in SINUS schools perceived classroom teaching as being more cognitively activating. Both interest and competencies were higher in SINUS schools compared to PISA schools. These positive results however must be differentiated. Positive results were more pronounced in SINUS schools with lower school tracks. Also the difference between SINUS-schools and PISA-schools is much higher in science as compared to mathematics.

Conclusions. The analysis of the second study 2003 (after the end of the programme) yielded valuable information concerning the most important criterion for success of professional development programmes: the improvement of student competencies and the increase of interest and motivation. The data suggest that especially students from lower track schools seem to benefit to a high degree from an effort like SINUS. However, it is not trivial to evaluate a professional development programme with hard measures when an implementation strategy is applied that purposely offers a considerable number of degrees of freedom in order to let teachers adapt their work to their local problem situations.

Discussion

In this article, professional development is viewed as a key factor in improving classroom instruction, a vehicle for conveying knowledge from research into classrooms, and an object of research itself. The quality development programme to improve instruction of science and mathematics in Germany presented here serves as an example to illustrate these three perspectives of professional development. We refer to this categorization in our discussion.

Professional development as a key factor to improve classroom instruction and to promote quality development. In this article, a professional development programme was outlined that has certain key characteristics. The SINUS pilot programme employs a problem-oriented approach to improve classroom instruction. Teachers are seen as the experts for instruction who are capable of cooperatively improving their own teaching. They do this within a frame of modules that refer to problem areas in German science and mathematics teaching and give a structure for support measures. Altogether, the SINUS project is an example of a professional development approach taking a perspective of situated learning. Teacher learning is located as close as possible to the daily task of the profession, classroom instruction (Borko, 2004; Borko et al., 2000; Putnam & Borko, 2000). The reaction from teachers and facilitators for the SINUS programme has been very positive. The decision was made to undertake the challenge of disseminating the approach to a larger number of schools. In a first phase of scaling-up, about 750 schools in 13 German federal states participated in the programme SINUS-Transfer. In a second phase of scaling-up (ending in July 2007), over 1,700 schools have been involved in the programme. From August 2007 on, it is the federal states' responsibility to use the built-up infrastructure and competencies of networks, facilitators and teachers and to further disseminate the SINUS approach to more schools. The central question for this enterprise is how to disseminate experiences and processes - not only products and developed materials - to a larger group of schools and teachers. It is agreed that the key elements of the programme (cooperative development of classroom teaching, framed by modules) have to be retained. In a way new schools and teachers have to start their own development from the beginning. Even so, the dissemination programme as a whole has been in a headstart position. New schools and teachers could draw on a huge amount of experience and developments from the pilot period. For instance, SINUS-experienced teachers could take over facilitator functions, a network of science and mathematics educators used to the SINUS approach had been established, and a vast amount of materials had been developed to inspire the teachers' work.

Another challenge of dissemination relates to the fact that the SINUS pilot-project was aimed at secondary science and mathematics instruction. For this reason, a programme started to transfer the approach to primary education. A special challenge is the fact that primary schools, in contrast to secondary schools in Germany, are not differentiated into performance-dependent school types. Another challenge lies in the fact that German primary teachers cannot rely on a very strong training in mathematical and science-related content knowledge.

Professional development as a vehicle to convey knowledge from research into classrooms. Transferring knowledge from mathematics, science and general education research into classrooms is considered a very significant problem. There is no direct way to accomplish this transfer. However, the SINUS approach tries to bridge this gap in building a support network where teachers can get help for their cooperative quality development. The problem-oriented way of working, using modules as a frame for development and support, seems to be a possible way to make the transfer of knowledge into practice more likely. Science and mathematics educators are increasingly recognized as holding helpful, scientifically-founded knowledge to foster quality development at the classroom level. However, teachers in general very carefully evaluate what they are offered, and it becomes apparent which educators are considered to give useful assistance for working on the modules.

Professional development as an object of research itself. Evaluation plays a crucial role in the programme. There are five questions we tried to answer that may be critical for the evaluation of the programme:

- Are the schools in the programme 'normal' schools? (Control of selection effects);

- How did the teachers engage in the programme? (Acceptance studies);
- What kind of support do teachers want? (Research on conditions for implementation);
- What products and understandings did the teachers develop? (Analyses of products and processes);
- What did the students learn? (Studies on the effectiveness of the programme).

So far the research in SINUS could be categorized as what Borko (2004) calls Phase 2 research. In Phase 2, research focuses upon a single professional development programme that is enacted by several facilitators in several sites.

For research in SINUS, case studies focussing on a single site – for example, a group of teachers from one school's subject department or one school network -- could lead to important additional insights into programme processes. These kinds of studies are categorized as Phase 1 research (Borko, 2004). Also interesting findings could be achieved in Phase 3 research, which compares different professional development programmes. In Germany, for example, there are professional development programmes on a national level that, in contrast to SINUS, do not primarily focus on classroom instruction in such a consequent manner. However, the same questionnaires have been used in one of these programmes making a comparison of teacher acceptance between the programmes possible.

SINUS seems to be a highly accepted programme that could be implemented in normal schools. The challenge, however, is to disseminate the approach. An important task in this respect is to foster the implementation of the specific ideas of the approach into the pre-existing support structures (institutes that offer conventional professional development). Institutes offering teacher training should increasingly take on a perspective of professional development that takes into view central problem areas of teaching and learning in science and mathematics. Central to all professional development initiatives should be teachers' learning related to daily pedagogical challenges in the classroom.

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Table 1: Programme modules:
The table shows the module name, a short description of the module as well as the number of schools working on the module during the pilot phase – (N=180 schools)

Module	*Problem area and emphasis of the specific work package the module refers to*
(1) Development of the task culture (114 schools)	Aims at a larger variety of tasks used in mathematics and science instruction (e.g. tasks that allow different ways of solving them) in situations where a new concept or phenomenon is introduced and elaborated, as well as when knowledge or skills are practiced or applied to new cases or situations (Lampert, 1990).
(2) Scientific inquiry and experiments (34 schools)	Emphasizes more open forms of experiments that allow active student participation; discourse among students about research questions, hypotheses, planning and interpreting an experiment; and understanding of the nature of science (Harlen, 1999; Lunetta, 1998).
(3) Learning from mistakes (33 schools)	Claims that mistakes are essential in learning, but to be avoided in achievement situations (F. Oser, Hascher, & Spychiger, 1999). Students' conceptions and mistakes are viewed as opportunities for learning, using conceptual change strategies as powerful tools (Duit, & Treagust, 1998).
(4) Securing basic knowledge – meaning-ful learning at different levels (47 schools)	Training tools are developed to compensate for student weaknesses. Tasks that allow solutions on different levels are constructed and used. In general it is important to differentiate between levels of understanding that can be reached by students starting with different learning pre-requisites (Prawat, 1989).
(5) Cumulative learning - making students aware of their increasing competency (39 schools)	Aims at higher coherence by linking the actual subject matter to the prior knowledge (principle of vertical linking). This module also stresses the differentiation and integration of conceptual knowledge in order to design cumulative teaching and learning sequences which make progress obvious for students.
(6) Towards integrated features of mathematics and science instruction (37 schools)	Aims at a better understanding of science phenomena by differentiating and linking the perspectives provided by the scientific disciplines, mathematics and other school subjects (DeCorte, Greer, & Verschaffel, 1996). In this multi-perspective instruction, more complex and meaningful applications of science can be treated and studied.
(7) Promoting girls' and boys' achievement and interest (9 schools)	Focuses on gender differences in the development of interest and possibilities for support. For example, by establishing differential courses or by embedding the content to be learned in contexts which are especially interesting for girls, but also for boys (Hoffmann, 2002).
(8) Development of tasks for co-operative learning (12 schools)	Students are stimulated to verbalize what they think, to argue and to deal with discrepant views and opinions, so that cooperative work will result in social learning as well as in cognitive gains (Linn, Songer, & Eylon, 1996).
(9) Strengthening students' responsibility for their learning (15 schools)	Supports students' readiness and ability for self-regulated learning within the context of the particular subject. Problems and tasks are to be solved independently and various means of repeating previously-learned knowledge are to be explored as well as supporting strategies for the self-structuring and self-monitoring of learning.
(10) Assessment: measuring and feedback on progress towards learning goals (14 schools)	Takes into account that the kind of assessment is of utmost significance for the success of instruction (Black, 1998; Crooks, 1988). The aim is to develop assessment tasks that allow the evaluation of students' progress beyond routine knowledge, including linking the newly-acquired with the already-known and application of understanding gained in new contexts and situations (Ruiz-Primo, Schultz, Li, & Shavelson, 2001; White & Gunstone, 1992).
(11) Quality development within and across schools (22 schools)	Functions on a meta-level in attempting to develop the conditions and cultures in the participating schools which are necessary for the success of the programme. The aim is to develop standards for science and mathematics instruction that are also valid beyond the participating schools (National Council of Teachers of Mathematics (NCTM), 1995).

Table 2: Teacher acceptance and contentedness with the programme

Scales to assess teachers' acceptance of cooperation, contentedness with the programme and perceived development throughout the programme. Comparison of means (scales with response categories from 'I strongly disagree' = 1 to 'strongly agree' = 4) from two points of measurement: Results of one-sample t-tests (t-values, degrees of freedom, p-values, effect sizes d). For comparing results of two points of measurement, data from the surveys in 2000 (N = 557 teachers) and in 2002 (N = 527) have been aggregated on school level.

	2000		2002					
Scale (number of items)	M	SD	M	SD	t	df	P	D
Teachers' acceptance of cooperation								
Effective cooperation (7)	3.14	0.51	3.29	0.45	- 2.81	108	<.01	0.27
Gain through cooperation (3)	3.16	0.48	3.32	0.49	- 3.11	107	<.01	0.30
Unhampered cooperation (3)	3.54	0.39	3.62	0.29	- 2.24	106	<.05	0.22
Teachers' contentedness with programme								
Appreciation of cooperative quality development (4)	3.49	0.33	3.63	0.31	- 4.77	110	<.01	0.45
Positive impulses for future classroom instruction (3)	2.61	0.51	2.87	0.50	- 4.68	108	<.01	0.45
No additional work load through programme activities (5)	2.76	0.50	3.07	0.38	- 6.51	109	<.01	0.62
Support by coordination on different levels (4)	3.02	0.51	3.09	0.45	- 1.54	110	Ns	0.15
Teachers' perceived development throughout the programme								
Perceived development regarding own professional competencies (3)	3.21	0.45	3.42	0.36	- 5.05	110	<.01	0.48
Perceived improvement with respect to classroom instruction (3)	2.61	0.46	2.93	0.39	- 7.38	108	<.01	0.71
Approval of programme activities from colleagues and parents (3)	2.01	0.42	2.28	0.39	- 6.26	111	<.01	0.59

Improving Science and Mathematics Instruction -

The SINUS-Project as an Example for Reform as Teacher Professional Development

Christian Ostermeier, Manfred Prenzel and Reinders Duit

IPN - Leibniz-Institute for Science Education, Kiel, Germany

Corresponding Author:

Christian Ostermeier
IPN – Leibniz Institute for Science Education
Olshausestr. 62
D 24098 Kiel, Germany
ostermeier@ipn.uni-kiel.de

Improving Science and Mathematics Instruction - The SINUS-Project as an Example for Reform as Teacher Professional Development

Abstract

This article presents an example of teacher professional development based on a perspective of situated learning and implemented on a large scale. We consider teacher professional development from three perspectives. First, teacher professional development is a key factor in improving classroom instruction. Second, teacher professional development is a vehicle for conveying knowledge from research into classrooms. Third, teacher professional development is an object of research itself. A German project to improve science and mathematics teaching (SINUS) – comprising 180 schools in a pilot-phase and more than 1,700 schools in a second phase of scaling-up – serves as an example of this framework for teacher professional development. Using these three views we describe the foundations of the programme and provide a brief account of the programme's background and its conception. We show how the central elements of the programme (11 modules) are based on an in-depth analysis of science and mathematics education, as well as how those modules structure the professional development of the teachers. Finally, we provide an overview of the evaluation of the programme. A large-scale comparison between SINUS schools and a representative sample of German schools tested in PISA 2003 showed positive effects of the programme with regard to students' interest and motivation as well as competencies in science and mathematics. In the light of these findings, we argue that teachers' learning related to daily pedagogical challenges in the classroom should be central to professional development initiatives.

Introduction

Teacher professional development is often discussed as one of the key factors in improving educational systems. Teachers constitute the key group of professionals acting in educational systems. In the following we will consider teacher professional development from three perspectives.

First, teacher professional development plays a crucial role in improving classroom instruction. Teachers are directly involved in designing learning environments for their students. They provide learning opportunities for their students, and thus have a major impact on learning processes and outcomes. Obviously, teachers are the pivotal target group when it comes to improving the quality of schools, instruction, learning and understanding. In this respect the professional development of teachers should be related to professional standards (National Council of Teachers of Mathematics (NCTM), 1991; Oser, 1997; Darling-Hammond & Bransford, 2005, Darling-Hammond, 2006). Besides these more or less normal demands, professional development could also foster teachers' competence to deal with and to solve educational problems in classrooms and schools.

Secondly, professional development can serve as a vehicle to convey research-based educational knowledge into classrooms. It must be emphasized that there is no simple and direct way to transfer findings and insights from research on learning, instruction and science and mathematics education into principles for acting in the classroom. Educational research provides background knowledge and tools for instruction. Educational research helps to identify problem areas of learning, teaching and schooling that could serve as a frame for professional development. Additionally, educational research can offer empirically-founded theories as scaffolds when teachers are tackling typical problems of their profession (Hiebert, Gallimore, & Stigler, 2002; Hewson, 2007).

From a third perspective, teacher professional development itself is an important and interesting object of educational research. More or less obvious are the questions of how professional development programmes for teachers are designed, how they can be implemented, and what impact they have on the participating teachers as well as on their classrooms, schools, and students. Besides the research on aspects of implementation and evaluation studies, the effects of professional development on teacher expertise is of special relevance (Garet, Porter, Desimone, Birman, & Yoon, 2001; van Driel, Beijaard, & Verloop, 2001).

In the following these three views of teacher professional development will be discussed in more detail. The different perspectives played a decisive role in the design of a professional development programme in the field of mathematics and science instruction. The aim of the programme was to improve the quality of mathematics and science education in Germany as a reaction to the findings of TIMSS and PISA. As this programme – called the SINUS project - has been enlarged during recent years from a pilot study (including 180 schools) to an extensive programme involving over 1,700 schools, it may serve as an example of a comprehensive attempt to improve the quality of education by means of teacher professional development. To classify the approach, two general directions of professional development can be discerned.

On the one hand, we find professional development programmes offered by institutes responsible for in-service teacher training. These institutionalized programmes comprise more or less conventional approaches to professional development and normally characterize the situation in many countries, including the U.S. or Germany (Sykes, 1996). This approach to professional development often attempts to transmit knowledge and skills by providing isolated training seminars dedicated to a specific topic. Often this kind of teacher professional development is regarded as less effective because it does not take into account the daily problems of classroom instruction.

On the other hand, there are professional development initiatives that are related to educational reform (Beeth, Duit, Prenzel, Ostermeier, Tytler, R., & Wickman, 2003; Beeth & Rissing, 2004; Krainer, 2005; Sykes, 1996; Tytler, 2007). These professional development programmes are often designed from a perspective of situated learning (Borko, 2004; Borko *et al.*, 2000; Putnam & Borko, 2000) and aim to relate teacher learning to the daily tasks of classroom instruction. The programme that will be outlined in the following is best classified as an example of this second approach as well.

Improving the Quality of Science and Mathematics Instruction: A Professional Development Programme

As an example of a programme for professional development that was designed from a perspective of situated learning and that relates to reform as a problem-oriented change process to improve science and mathematics teaching, we will describe one approach taken in Germany in more detail. We discuss the programme using the three perspectives mentioned in the beginning.

Professional Development as a key to promote Quality Development

In this section, we give a structured overview of the programme by employing the four key elements of professional development suggested by Borko (2004): (a) The professional development programme; (b) the teachers, who are the learners in the system; (c) the facilitators, who guide teachers as they construct new knowledge and practices; and (d) the context in which the professional development occurs.

(a) The professional development programme: SINUS

Before describing the approach to professional development in the following section, we briefly describe the background of the programme. The responsibility for school teaching in Germany, as, for example, in the United States of America, lies within the administrative authority of each of the federal states ('Länder'). The Third International Mathematics and Science Study (TIMSS) (Beaton *et al.*, 1996a; Beaton *et al.*, 1996b) and German students' mediocre performance strongly aroused public interest. An effort to tackle the problematic findings was considered necessary.

Thus, the German federal government, in cooperation with the federal states, commissioned a group of experts to develop a framework in preparation for the set-up of a programme to increase the efficiency of mathematics and science instruction (Bund-Länder-Kommission für Bildungsplanung und Forschungsförderung, 1997). The conception of the programme was based upon an analysis of problem areas of German mathematics and science teaching (Baumert, Bos, & Lehmann, 1998; Baumert et al., 1997; Bund-Länder-Kommission für Bildungsplanung und Forschungsförderung, 1997). The major goal of the programme is to improve classroom instruction in mathematics and science and, in doing so, to foster student learning and understanding, as well as motivation and interest in those domains. There are four central characteristics of the programme aimed at achieving those goals.

First, the programme refers to central problem areas in German mathematics and science teaching as pointed out, for example, by the TIMSS 1995 Video Study (Stigler & Hiebert, 1997). The problem areas are conceptualized into 11 modules that provide a framework for improving classroom instruction (Table 1). Schools in the programme had to choose at least two modules to work on. Modules are not preformed teaching units or whole science or math programmes. Rather, they outline central aspects of the problem area and provide examples of how to overcome the identified shortcomings. Modules serve as a starting point and frame to improve teaching. They also help to categorize the documentation of processes and products (developed units, materials, etc.) and provide a shared language to facilitate communication about science and mathematics teaching. The choice of a system of modules also makes professional development adjustable to the specific local situation and problems in the participating schools. In which way these modules provided the framework for the work of the participating teachers and examples for the role the modules played in the practice of the work in the school sets is more fully described below.

INSERT TABLE 1 ABOUT HERE

Second, the programme introduces processes of quality development at the level of the participating schools. The teachers are encouraged to set their specific working goals, to develop new materials or modify existing approaches, and engage in self-evaluation methods that are easily applied to their classroom teaching. To ensure steady and sustainable improvement, teachers first are sensitized to typical problems in mathematics and science teaching. A culture of feedback is considered crucial in order to detect problems and work on them. The programme seeks to draw upon the collective wisdom inherent in the communities of colleagues. In the long run, an enduring system to ensure the quality of teaching should develop at the school level.

Third, the programme's leading principle is cooperation and collaboration on different levels, especially between the teachers participating in the programme. In German schools, cooperation is rather uncommon (Terhart, 1987). Nonetheless, according to school effectiveness research, collaboration among teachers constitutes a main characteristic of effective schools (Sammons, 1999; Scheerens & Bosker, 1997). Also professional development initiatives prove to have the greatest effect if a group of colleagues from one school is engaged in the activities (Garet et al., 2001). However, although collaboration certainly is a key feature of effective teacher professional development programmes it is claimed that teachers usually are not used to cooperative norms (Roth, 2007, 1236).

Fourth, the teachers' work is supplemented by support from science and mathematics educators and through research on learning and instruction. Teachers working on modules have access to scientifically-based materials and worked-out examples referring to the modules. There are also various possibilities for consultation and in-service training offered within the programme.

(b) Teachers as the learners in the system

Teachers are the group of professionals who have immediate influence to improve learning environments in classrooms. Therefore, the best chance to increase student competencies and motivation is to devote a programme to the professional competencies of in-service teachers.

Different forms of teacher involvement exist in the programme. The basic level of involvement is the cooperative work of science and/or mathematics teachers at a particular school. That is, the smallest unit of cooperation is the subject department. This can be the physics, biology, chemistry or the mathematics department (or some combination, if two, three or four departments take part). In addition to cooperating at the school level, teachers work together across school boundaries. To foster this level of cooperation, the programme schools are organized into small school networks (school sets) of six schools each.

Teachers in the programme are seen as the experts in teaching and learning who are capable and responsible for further developing and improving their own classroom teaching. In order to do so, they have an array of problem areas (modules) with which they can frame their work, and they share their thoughts and ideas with their colleagues. The teachers, who are the learners in the programme, are seen as reflective practitioners (Schoen, 1987) who work in a self-directed and cooperative way. The teachers in the particular school sets decide which of the deficits of actual science and math instruction described by the 11 module in table 1 they want to address in their work. As mentioned already the work on developing and evaluating new teaching and learning methods provides many opportunities to rethink their normal views of good teaching and learning.

(c) The facilitators, who guide teachers as they construct new knowledge and practices

The cooperative work of the teachers is supported on different levels. In each school, there is one person coordinating the programme activities at the school level. In addition, the schools are organized in small school networks. Each school network has at least one coordinator who gives technical support and guides and structures the classroom-related work of the teachers. Besides the coordination of the school networks, several support structures are located at the level of the participating federal states. Local district authorities and ministries of education, as well as the states' in-service training institutes, serve as valuable assets for the infrastructure of the programme. Additionally, the people in charge of the programme in each state are encouraged to cooperate closely with faculty and staff of local universities and to utilize the knowledge and experience of science and mathematics educators and researchers studying learning and instruction.

As a result, staff responsible for teacher training is familiarized with the approach to professional development suggested by the programme – that is, teachers improving their own classroom teaching in a collaborative way over a longer period of time within a conceptual framework related to problem areas (modules) of science and mathematics teaching. Thereby the existing institutions of teacher training will experience a steady influence in the direction of a long-term and school-based professional development approach designed from a perspective of situated learning.

(d) The context in which the professional development occurs

The TIMS-study (Baumert et al., 1997; Beaton et al., 1996a; Beaton et al., 1996b) gained a high level of interest in German public discussion. This has been the most important reason for developing the programme SINUS. However, the professional development programme occurs in a special educational context that is characterized by the following aspects. Clearly, most of these aspects are also well known in the context of other countries:

- The general appreciation of mathematics and science and corresponding school subjects – or even school and education in general – is rather low in Germany and elsewhere (Koballa & Glynn, 2007; Duit, Niedderer, & Schecker, 2007). Often success and failure in mathematics and science subjects is only attributed to ability. Thus, efforts to improve one's competencies appear not to be worthwhile from the students' point of view.
- There is a high degree of individualism of teachers in German schools (Terhart, 2000). Most commonly the teacher is a "lone warrior" who almost never opens her or his classroom door in order to share teaching experiences with colleagues (c.f. the above remarks on the necessity to guide teachers to close cooperation).
- There are almost no incentives to engage in professional development. Schools and districts do not have systematic requirements to participate in in-service-training. However, some federal states have started to make in-service professional training compulsory.
- Existing support systems tend to offer in-service-training without taking much account of teachers' needs. Professional development is seldom oriented towards the actual demands of teachers. Often "one-shot training" is offered that is not part of a coherent curriculum.

Additionally, universities do not play a substantial role in teacher professional development (c.f., Sykes, 1996).

In conclusion, there is a high level of need for professional development that takes into account the demands of daily classroom teaching and support systems that are demand-oriented. Instead of stand-alone training, in-service-training should be embedded into a classroom-related professional development structure that focuses on continuous development. The professional development approach outlined above takes those aspects very seriously and adheres to them in multiple ways as will be outlined more fully below. Briefly put there are the following key features: (1) Teacher cooperation as a basic principle of the programme; (2) a long term approach of professional development with a significant focus on classroom teaching instead of a one shot attempt.

Professional Development as a Vehicle to convey Knowledge from Research into Classrooms

The starting point for the teachers' work is the set of 11 modules. Findings from research on learning and instruction, educational psychology, and science and mathematics education are the foundations of the modules (e.g., Häußler, Bünder, Duit, Gräber, & Mayer, 1998). Science and mathematics educators are engaged to support the professional development on various levels. The modules are a frame of reference for support. Within the frame of the modules, written materials, in-service training or consultation is offered to the teachers developing their own classroom instruction. In the following we choose module 2 "Scientific inquiry and experiments" in order to (1) demonstrate how scientifically-based knowledge is introduced into the modules and to (2) show the ways teachers are introduced to the basic ideas of the modules.

(1) The foundation of each of the modules is a thorough analysis of the current state of the art of research in science and mathematics education and research on learning and instruction in general (Seidel & Shavelson, 2007). Module 2 "Scientific inquiry and experiments" takes up the current academic discussion of scientific work and experiments and their effect in science classrooms (Harlen, 1999; Hofstein & Lunetta, 2004; Tesch & Duit, 2004; Seidel & Prenzel, 2006). The use of scientific inquiry and experiments in classroom learning has been studied thoroughly in science education. For instance, White and Frederiksen (1998) showed that students learning with an inquiry approach improved significantly on physics as well as

inquiry assessments. Furthermore, positive effects on students' attitudes towards science could be observed (George & Kaplan, 1998). However, studies focussing on the role of student experiments do not yield such a clear picture. The mere implementation of student experiments does not seem to have a positive impact. Rather, the way in which experiments are embedded in classroom instruction and the way in which science is represented by inquiry and scientific investigations seems to be more crucial to student learning and attitudes (Harlen, 1999). In order to integrate experiments and scientific investigation and inquiry in classrooms with the goal of enhancing student thinking and deeper understanding, some principles can be drawn from research in science education (Harlen, 1999; Hofstein & Lunetta, 2004; White & Frederiksen, 1998):

- Experiments should be both challenging and thought-provoking. They also should stimulate students' interests.
- The students need to have a clear picture about the intention of the experiment.
- The main objective for employing student experiments is learning and deeper understanding. Students have to deal with an idea and not just act upon or handle scientific equipment.
- Students need to be given the choice to plan and interpret their own experiments.
- Experiments should support students to work in a self-directed manner.
- Scientific inquiry and experiments should bring about experiences of competence for students.

(2) As mentioned previously, the teachers of each participating school decide upon the focus of their work. There are several ways in which the teachers are introduced to the basic ideas of the modules. Typically the group of teachers at a participating school chooses at least two to three modules to work on. They can also access an array of module-specific support measures like basic written module descriptions (which also include brief summaries of research findings), module-related classroom materials and in-service training-workshops.

A first way to get acquainted with the idea of the module is through the basic written module description. These papers include a brief introduction to the problem area and its empirical foundation. A description of shortcomings of "traditional" instruction addressed by the module is typically followed by specific examples of possibilities to overcome these problems in classroom instruction. In module 2, for example, teachers are introduced to the state of empirical research knowledge concerning the role and use of experiments outlined above and also how experiments may be used to make students familiar with the particular role of the experiments within the other science processes and within science inquiry. Exemplary experiments described in the basic description serve as examples teachers may use as “models” for designing their own experiments.

Besides the basic module descriptions, there is of course a considerable amount of module-related reform-oriented material available to the teachers. There are many “best practice” examples provided especially by science and mathematics educators from universities and teacher-training institutes. The internet server of the programme plays a crucial role in managing and providing this module-related information. However, a critical view is in place here. The work in the school sets of teachers showed that some of the material was too complicated and papers were too long for many teachers. Much guidance was necessary to allow the teachers to make fruitful use of the many materials provided. In other words, materials provided usually are used by teachers in their own ways. Davis and Krajzik (2005) point out that “educative” materials need to be provided, i.e., presentation of the materials should be closely linked with the intentions they were developed.

Another important way to introduce teachers to the basic content of the modules is through in-service training sessions. These sessions typically start with a brief introduction to the module-specific ideas and their research base. A main focus, however, is to offer innovative module-related examples that can be applied to classroom instruction. The basic idea is that teachers develop their views about good instruction by trying out new examples and sharing the experiences with the group of colleagues at the school or school network level.

In summary, modules serve as a frame of reference for teacher professional development and support. They are based on current research on learning and instruction, especially in the domains of science and mathematics education. Science and mathematics educators, as experts on module-related topics, are engaged to support the teachers’ work. As a result, a network of support is being built throughout the country. Through the set of modules, research-based knowledge can find its way into “normal” classrooms. However, the route is not a direct one. An important characteristic of the kind of professional development in the SINUS programme is that it is oriented towards key problem areas. The teachers can locate their own crucial classroom-related problems within the frame of the modules and are then supplied with examples that help to solve those problems.

Professional Development as an Object of Research:

Evaluation of the SINUS-Programme

In this section, we present an overview of the research accompanying the professional development programme. We used different approaches for evaluation that served different purposes. Means of formative evaluation played a significant role in order to support the work in the individual sets. In the following, we focus on findings of research linked to key features of the professional development programme. We will try to answer some questions that are essential for the evaluation of the programme:

- *Are the schools in the programme 'normal' schools? (Control of selection effects).* This question refers to the control of possible selection or sampling effects.

- *How did the teachers engage in the programme?* The second question deals with the acceptance and appreciation of the programme by the teachers. This is a necessary condition for success. We are interested, for instance, to assess the extent of teachers' agreement with the programme's philosophy and how they put the programme into practice.

- *What kind of support do teachers want? (Research on conditions for implementation).* Most interesting for the management of the programme is information about conditions that foster or hamper the realization of important principles of the programme. For example we looked at the support the teachers wanted.

- *What products and understandings did the teachers develop? (Analyses of products and processes).* The success of the programme finally depends on the output. In this respect we looked at the materials the teachers developed themselves. Finally, an important aspect of investigation is the effects on the students.

- *What did the students learn? (Studies on the effectiveness of the programme).* This question deals with the major goal of the professional development programme: to increase student competencies and motivation in science and mathematics.

In the following we refer to these questions in describing the purpose of the investigation, the design of the study and methods used as well as the results. We end by drawing conclusions about each of the questions.

(a) Are the schools in the programme 'normal' schools? (Control of selection effects)

Purpose of the investigation. Our first aim was to check the sample of schools. Professional development programmes may attract schools and teachers who are already more engaged in innovation than others. In order to disseminate the programme conception to a wider range of schools, it is important to rule out the hypothesis that the approach only worked because of more favourable conditions at the programme schools. Thus, we wanted to investigate whether the participating schools were a special sample with regard to classroom- and school-related preconditions. Relevant conditions refer to mathematics- and science-specific cognitive and motivational student variables at the school level, as well as more general student ratings about the school (e.g. school climate).

Design of the study. 171 programme schools were tested in a first study in 2000 to answer these questions. The instruments were selected from our national extensions of the PISA study so that a comparison of SINUS-schools to a representative sample of German schools (PISA/E 2000 - an extended PISA-sample) could be made.

Results. Our data show no meaningful differences between the PISA sample and the programme schools in the first assessment (year 2000) (Ostermeier, Carstensen, Prenzel, & Geiser, 2004). The schools did not differ with respect to resources, staff, programmes, experiences with innovations and school climate. Also we found comparable levels of interest, motivation and self-concept. Most importantly the programme schools did not systematically show a higher or a lower performance on the mathematics and science assessments.

Conclusions. Overall, the programme schools did not differ systematically compared to a nationally representative school sample. This result is an important prerequisite for the dissemination of the programme approach. It is more likely to successfully disseminate an approach tested in "normal" schools, whereas it would seem almost impossible to do this with an innovation tested only in the most excellent schools. In addition, the data from the first study will serve as a baseline for the investigation of changes in student competencies and interests towards the end of the programme.

(b) How did the teachers engage in the programme?

Purpose of investigation. The programme has been conceptualized by integrating research findings on school innovation and reform showing that changes of professional actions are most likely to occur when they are appreciated by the main actors, the teachers, and become part of their professionals' routines (Anderson & Helms, 1999; Brown, 1997; Knapp, 1997; Stake, Burke, Flôres, Whiteaker, & Irizarry, 1997). Hence, investigating teachers' views of the intentions of the programme and their appreciation of the work within the sets also serve the purpose of formative evaluation, i.e. provide significant information on improving the actual work.

Design of the study. Questionnaires were designed containing questions about the degree to which the teachers appreciated the programme and its goals. Specifically, items were developed to study how engaged the teachers are in the cooperative quality development, how the teachers accept the cooperation, how content they are with programme activities, and how they perceive the development of their professional competencies throughout the programme. The teachers were also asked to assess the quality of the support provided as well as to give an account of their actual use of this assistance.

Clearly, questionnaires provide a somewhat limited picture of teachers' appreciation of the programme. But they are the only means to gain data that allow comparing the views of teachers in the participating sets all over Germany. Additional data on teacher appreciation are available on the level of the individual sets provided by various methods of formative evaluation (like protocols of meetings).

Two surveys were conducted during the pilot phase of the programme. In 2000, a total of 557 teachers, and in 2002, 527 teachers completed the questionnaire. Because of data protection regulations, data from the two points of measurement could not be linked on an individual level. However, data from both times can be compared using data aggregated at the school level (Table 2). Although the participating teachers were the main target group, we additionally included other groups in our study, namely the principals of the schools, the coordinators, as well as small samples of parents and students from the schools.

Results. The results of both surveys suggest that participating teachers engage in programme activities to a high degree. In general, teachers invest a lot of time in cooperative quality development. The additional time spent on programme-related activities exceeds the amount of reduction of teaching load to a significant degree.

Teachers report exchanging programme-related materials, cooperative clarification of goals, working together on modules, cooperatively reflecting on teaching, and receiving as well as providing feedback on cooperatively-developed materials. Naturally, the frequency of those activities is higher at the level of the schools. Cooperation at the level of the school networks takes place less often but is still remarkably high, bearing in mind the considerable effort needed to get together at this level.

As a next step, we looked at how the teachers' ratings developed throughout the course of the pilot programme. Table 2 shows results for those three aspects for the two points of measurement: the surveys in 2000 (N = 557 teacher responses) and in 2002 (N = 527) (Ostermeier, 2004). For comparison of the two points of time, data were aggregated at the school level (scales with response categories from 'I strongly disagree' = 1 to 'strongly agree' = 4).

- *Teachers' appreciation of cooperation.* Three aspects regarding cooperation in the professional development programme were assessed (Table 2). Each aspect was operationalized by a scale comprising three to seven items, with the first one referring to what degree teachers experience cooperation as being effective. The second scale includes items that assess to what extent the participants experience a gain for their professional work through cooperation. The last aspect deals with issues that could foster or hamper cooperation and is labelled "Unhampered cooperation". As Table 2 shows, teachers rate all three aspects rather positively. The ratings even increase in the second survey.
- *Teachers' contentedness with programme activities.* The next step was to study how content the teachers are with different features of the programme. For example, items referred to collaboratively developing and testing new approaches in classroom instruction (scale labelled "Appreciation of cooperative quality development") or getting new ideas for future classroom instruction. Two further scales related to the amount of additional work load through programme activities and the support and consultation provided by coordination on different levels. As in the ratings referring to the assessment of cooperation, teachers' answers were positive. Except for one scale ("Support by coordination on different levels"), the already positive ratings increase significantly in the second survey.
- *Teachers' perceived development throughout the programme.* Teachers were asked to rate how they perceive the development of their own professional competencies, how they perceive improvement with respect to classroom instruction, and how they perceive the support and approval of programme activities from parents and colleagues not participating in the project. Again, ratings are significantly higher at the second

measurement point. As in the two former areas, ratings are also very positive. However, there is one exception in this positive appraisal. Participating teachers rate the approval and appreciation of the programme expressed by non-participating colleagues and parents rather low. Although those ratings are significantly higher in 2002, they are still below the theoretical mean (2.5) of the scale.

INSERT TABLE 2 ABOUT HERE

Conclusions. In general, findings indicate engaged teachers. The appreciation of the professional development programme seems to be high. Also appreciation does not decrease over the course of the pilot phase. Two findings seem to be of particular relevance. First, teachers' appreciation of cooperation increases significantly during the work in the programme. Second, teachers rated their personal gain of participation significantly higher in the second survey.

(c) What kind of support do teachers want? (Research on conditions for implementation)

Purpose of investigation. Information from the above questionnaire on teachers' appreciation can be interpreted as information on conditions for successful implementation of the programme. An important question in this respect is, for example, how teachers use and appreciate the offered support: What kind of support do teachers prefer or request? We also used the above teacher questionnaires to ask some questions which could help to identify conditions of a successful implementation of the programme. We were, for instance, interested to learn which conditions support or hamper the implementation of the central principles of the programme.

Design of the study. We also used the data of the above studies in 2000 and 2002. Teachers were, for instance, asked to rate the extent to which they would need more of the following aspects: autonomy for programme work, supply of written materials, training meetings, possibilities of mutual exchange, precise instructions, and a precise determination of the goals for the programme work at the school (Ostermeier & Prenzel, 2005).

Results. The requests for support do not point in a specific direction. Nearly one half of the teachers want more support concerning each item, whereas the other half long for less. The data structure seemed suitable for running a Latent Class Analysis, looking for different patterns or types of requests. With LCA we could identify three groups of teachers. Two groups had in common that teachers wanted to get more material and wished for more precise instructions and a precise determination of the goals for the programme. The third group emphasized the need for mutual exchange, whereas the level of request for materials or precise instructions and goal determination was rather low. This group of teachers seems to be in line with the philosophy of the programme. They request ideas and suggestions, but they want to explore new approaches by themselves (Ostermeier & Prenzel, 2005).

We also found important differences between these request-groups concerning the use of support, the time spent on programme activities, and the perception of local coordination. The third group of teachers seems to use the support offered to a higher degree and to spend more time on programme activities. Those teachers also rate the local coordination more positively (Ostermeier & Prenzel, 2005). In 2002, similar groups could be identified by LCA. The third group of teachers thereby increased in size after more experiences with the programme (Prenzel & Ostermeier, 2006).

Conclusion. The results indicate that a key feature is the coordination at all levels (school, set, state). The request types especially show that coordination on the level of the federal states, as well as the coordination of the small school networks, is crucial. There are different coordination approaches in the federal states that seem to have an impact on the way teachers engage in the programme.

The different groups of teachers seem to need different support and treatment in the programme. Therefore, we drew the attention of the coordinators to different styles of engagement and needs and sensitized the facilitators to carefully take account of these differences.

(d) What products and understandings did the teachers develop?

(Analyses of products and processes)

Effects of modules. We refer to effects of the framework supplied by the modules and to teachers' experiences with the programme. We also report an example with regard to what products the teachers developed.

Experiences in the pilot phase. Very interesting effects of the modules find expression in visible products. They can be found on the internet server of the programme – both the internal and external sites – but also in a large number of publications.

These products include the outlines, worked-out examples, and materials, which have been provided by the scientific managers of the programme. In addition, there are a large number of materials, teaching units, classroom projects, curricula, and collections of tasks that have been developed by the groups in the schools. For example, a group of teachers working on Module 2 "Scientific inquiry and experiments" developed a learning setting where students approach chemical phenomena by observing experiments in groups of three or four. Students are asked to describe their observations and think aloud about their ideas. The purpose of this setting is mainly to stimulate the students' pre-instructional knowledge structures and to make their basic scientific ideas transparent so that further learning can be linked to them. The students' classroom interactions were videotaped and published on a CD along with comments that can be used to stimulate other teachers working on module two (Stamme & Stäudel, 2000).

With the support of local and central coordinators, a large portion of these materials is presented in a systematic module-specific way. A lot of these materials can be downloaded from the central internet server of the programme, as well as from the regional programme web pages of the participating federal states. The internet server is frequently used to gather information and to download module-related materials (Strecker, 1999). Also a huge amount of module-related approaches have found their way into written publications (Hertrampf, 2003). In the two phases of scaling-up (2003-2007) we used the portfolio-method to support and evaluate teacher professional development (Barton & Collins, 1993; Craig, 2003; Tucker, Stronge, Gareis, & Beers, 2003). We designed a tool (subject department portfolio) that requires teachers of one school to collaboratively document and reflect on efforts to improve their teaching and to make their thoughts and developments accessible to others (Meentzen, Ostermeier, & Prenzel, 2006). About half the schools were randomly chosen and asked to send in copies of their portfolio. The analyses of those portfolios promise to produce valuable insights into the products the teachers developed and the learning processes the teachers went through. Due to the large amount of qualitative data results will be available after the scaling-up-project ended in 2007.

Conclusions. The experience in the programme indicates that a necessary condition for a professional development programme is to bring teachers into a situation where they have to deal with new approaches very early. Therefore, we consider it crucial that they experience these new approaches in a carefully-designed framework (modules), so that the chance that they might fail with new approaches is reduced to a minimum and the chance to experience success is increased. In this respect, the modules show concrete ways to improve instruction step-by-step, and they increase the probability that changes can be integrated in teachers' routines.

(e) What did the students learn? (Studies on the effectiveness of the programme)

Purpose of investigation. As a significant feature of the summative evaluation we asked how we could study the "effectiveness" of the pilot programme. As the about 1000 participating teachers from the 180 schools developed rather different new instructional approaches and materials such a study is rather difficult to design. We decided to use the framework of school effectiveness employed in the PISA studies. In particular, a sample of 144 SINUS schools became part of a national extension of the German PISA sample in 2000 and 2003 (Prenzel, Carstensen, Senkbeil, Ostermeier, & Seidel, 2005).

Design of the study. The programme schools were assessed with PISA instruments in 2000 and again in 2003 (N=144 schools). Instruments assess the students' mathematics and science competencies and their motivation. In addition a set of items provides information on students' perceptions of their science and math instruction (e.g., on the role of everyday examples, the extend stimulating questions were asked, and how often challenging applications of science and math knowledge were provided). Thus, the design allows us to evaluate the progress, at the school and programme level, in the students' mathematics and science performance, interest, and perception of instruction experienced, as compared to a national sample of schools not participating in the programme. Additional school and teacher questionnaires provide information on teacher cooperation, school programme and evaluation policies.

Results. The results of the 2003 comparison of SINUS and PISA-schools indicate that SINUS showed positive effects in all areas investigated. The teachers in SINUS schools report more cooperation activities at the school level. Both student interest and competencies were higher in SINUS schools compared to PISA schools. Students in SINUS schools also perceived classroom teaching as being more cognitively activating. Hence, there is empirical evidence in our study that instruction actually changed in the desired direction in SINUS schools as compared to other schools.

These positive results however must be differentiated. Positive results were more pronounced in SINUS schools with lower school tracks. Also the difference between SINUS-schools and PISA-schools is much higher in science as compared to mathematics.

Conclusions. The analysis of the second study 2003 (after the end of the programme) yielded valuable information concerning the most important criterion for success of professional development programmes: the improvement of student competencies and the increase of interest and motivation. The data suggest that especially students from lower track schools seem to benefit from an effort like SINUS.

Discussion

In this article, professional development is viewed as a key factor in improving classroom instruction, a vehicle for conveying knowledge from research into classrooms, and an object of research itself. The quality development programme to improve instruction of science and mathematics in Germany presented here serves as an example to illustrate these three perspectives of professional development.

Professional development as a key factor to improve classroom instruction and to promote quality development. The SINUS programme presented here employs a problem-oriented approach to improve classroom instruction. Teachers are seen as the experts for instruction who are capable of cooperatively improving their own teaching. They do this within a frame of modules that refer to key problem areas in German science and mathematics teaching. The SINUS project is an example of a professional development approach taking a perspective of situated learning. Teacher learning is located as close as possible to the daily task of the profession, classroom instruction (Borko, 2004; Borko et al., 2000; Putnam & Borko, 2000). The reaction from teachers and facilitators for the SINUS programme has been very positive. The decision was made to undertake the challenge of disseminating the approach to a larger number of schools. In a first phase of scaling-up, about 750 schools in 13 German federal states participated in the programme SINUS-Transfer. In a second phase of scaling-up (ending in July 2007), over 1,700 schools were involved in the programme. From August 2007, it is the federal states' responsibility to use the built-up infrastructure and competencies of networks, facilitators and teachers and to further disseminate the SINUS approach to more schools. The central question for this enterprise is how to disseminate experiences and processes - not only products and developed materials - to a larger group of schools and teachers. It is agreed that the key elements of the programme (cooperative development of classroom teaching, framed by modules) have to be retained. In a way new schools and teachers have to start their own development from the beginning. Even so, the dissemination programme as a whole has been in a headstart position. New schools and teachers could draw on a huge amount of experiences and documents from the pilot period. For instance, SINUS-experienced teachers could take over facilitator functions, a network of science and mathematics educators used to the SINUS approach was established, and a large amount of materials was developed to inspire the teachers' work.

A particular challenge of dissemination relates to the fact that the SINUS project aimed at secondary science and mathematics instruction. For this reason, a programme started to transfer the approach to primary education. A special challenge is the fact that primary schools, in contrast to secondary schools in Germany, are not differentiated into performance-dependent school types. Another challenge is the fact that German primary teachers cannot rely on a very strong training in mathematical and science-related content knowledge.

Professional development as a vehicle to convey knowledge from research into classrooms
Transferring knowledge from mathematics, science and general education research into classrooms is considered a very significant problem. There is no direct way to accomplish this transfer. However, the SINUS approach attempts to bridge this gap in building a support network where teachers can get help for their cooperative quality development. The problem-oriented way of working, using modules as a frame for development and support, seems to be a possible way to make the transfer of knowledge into practice more likely. Science and mathematics educators are increasingly recognized by teachers as holding helpful, scientifically-founded knowledge to foster quality development at the classroom level. However, teachers in general very carefully evaluate what they are offered, and it becomes apparent which educators are considered to give useful assistance for working on the modules.

Professional development as an object of research itself. Formative and summative evaluation play a crucial role in the programme – first, to gain information on the "effects" of the programme but also to contribute to research on professional development in general. As is more fully outlined above, the findings of the various studies carried out provide reliable and valid research knowledge on professional development.

In a nutshell, the SINUS programme seems to be a highly accepted programme that can be implemented in normal schools. The challenge, however, is to disseminate the approach. An important task in this respect is to foster the implementation of the specific ideas of the approach into the pre-existing support structures (institutes that offer conventional professional development). Institutes offering teacher training should increasingly take on a perspective of professional development that takes into consideration key problem areas of teaching and learning in science and mathematics. Central to all professional development initiatives should be that teachers' learning is related to daily pedagogical challenges in the classroom.

The results of the evaluation presented paint a generally positive picture indicating considerable "success" of the programme. However, we are aware of a number of limitations – of the programme and the evaluation. The role of the parents in improving instruction needs more attention than we gave that issue so far. It has also to be taken into account in which way the teachers in a school who did not participate may be integrated. There are several cases of such teachers who kept to be sceptical and did not like to be part of the programme. Also the support materials used (especially the description of the modules) need to be considerably revised as they often were too long and to complicated for many teachers. Finally, we would like to briefly comment on a concern of the two reviewers of the present paper. They argued that our evaluation does not provide much information on changes of teachers' subjective theories about efficient teaching and learning science and math as well as about changes of their instructional behaviour. Clearly, these are essential features when evaluating programmes on teacher professional development. We admit that more data on these features would be most desirable. However, our studies on the effectiveness of the programme also include student data on their perception of instruction as outlined above. Further, teacher questionnaires used provide information in which way they perceived the way they changed views during participation.

We would like to add a few additional remarks. First, the approach of the SINUS programme was recently recommended as a model for improving science education in Europe (European Commission, 2007). Second, also in Germany the SINUS approach has become a "model" standing for renewed science and math education – on the levels of ministries of education, school administration, teacher education, the teachers, and research on teaching and learning. Third, the SINUS programme is a central part of various activities on various levels in Germany to improve science instruction. It provided, for instance, significant features adopted by the programmes “Chemistry in Context”[1], “Physics in Context”[2], and “Biology in Context”[3] that deal with improving, chemistry, physics and biology instruction and have a strong focus on teacher professional development as well.

[1] http://www.ipn.uni-kiel.de/abt_chemie/chik.html (29/07/2008)

[2] http://www.uni-kiel.de/piko/ (29/07/2008)

[3] http://bik.ipn.uni-kiel.de/ (29/07/2008)

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Table 1: Programme modules
The table shows the module name, a short description of the module as well as the number of schools working on the module during the pilot phase – (N=180 schools)

Module	*Problem area and emphasis of the specific work package the module refers to*
(1) Development of the task culture (114 schools)	Aims at a larger variety of tasks used in mathematics and science instruction (e.g. tasks that allow different ways of solving them) in situations where a new concept or phenomenon is introduced and elaborated, as well as when knowledge or skills are practiced or applied to new cases or situations (Lampert, 1990).
(2) Scientific inquiry and experiments (34 schools)	Emphasizes more open forms of experiments that allow active student participation; discourse among students about research questions, hypotheses, planning and interpreting an experiment; and understanding of the nature of science (Harlen, 1999; Lunetta, 1998).
(3) Learning from mistakes (33 schools)	Claims that mistakes are essential in learning, but to be avoided in achievement situations (Oser, Hascher, & Spychiger, 1999). Students' conceptions and mistakes are viewed as opportunities for learning, using conceptual change strategies as powerful tools (Duit, & Treagust, 1998).
(4) Securing basic knowledge – meaning-ful learning at different levels (47 schools)	Training tools are developed to compensate for student weaknesses. Tasks that allow solutions on different levels are constructed and used. In general it is important to differentiate between levels of understanding that can be reached by students starting with different learning pre-requisites (Prawat, 1989).
(5) Cumulative learning - making students aware of their increasing competency (39 schools)	Aims at higher coherence by linking the actual subject matter to the prior knowledge (principle of vertical linking). This module also stresses the differentiation and integration of conceptual knowledge in order to design cumulative teaching and learning sequences which make progress obvious for students.
(6) Towards integrated features of mathematics and science instruction (37 schools)	Aims at a better understanding of science phenomena by differentiating and linking the perspectives provided by the scientific disciplines, mathematics and other school subjects (DeCorte, Greer, & Verschaffel, 1996). In this multi-perspective instruction, more complex and meaningful applications of science can be treated and studied.
(7) Promoting girls' and boys' achievement and interest (9 schools)	Focuses on gender differences in the development of interest and possibilities for support. For example, by establishing differential courses or by embedding the content to be learned in contexts which are especially interesting for girls, but also for boys (Hoffmann, 2002).
(8) Development of tasks for co-operative learning (12 schools)	Students are stimulated to verbalize what they think, to argue and to deal with discrepant views and opinions, so that cooperative work will result in social learning as well as in cognitive gains (Linn, Songer, & Eylon, 1996).
(9) Strengthening students' responsibility for their learning (15 schools)	Supports students' readiness and ability for self-regulated learning within the context of the particular subject. Problems and tasks are to be solved independently and various means of repeating previously-learned knowledge are to be explored as well as supporting strategies for the self-structuring and self-monitoring of learning.
(10) Assessment: measuring and feedback on progress towards learning goals (14 schools)	Takes into account that the kind of assessment is of utmost significance for the success of instruction (Black, 1998; Crooks, 1988). The aim is to develop assessment tasks that allow the evaluation of students' progress beyond routine knowledge, including linking the newly-acquired with the already-known and application of understanding gained in new contexts and situations (Ruiz-Primo, Schultz, Li, & Shavelson, 2001; White & Gunstone, 1992).
(11) Quality development within and across schools (22 schools)	Functions on a meta-level in attempting to develop the conditions and cultures in the participating schools which are necessary for the success of the programme. The aim is to develop standards for science and mathematics instruction that are also valid beyond the participating schools (National Council of Teachers of Mathematics (NCTM), 1995).

Table 2: Teacher appreciation and contentedness with the programme

Scales to assess teachers' appreciation of cooperation, contentedness with the programme and perceived personal development throughout the programme. Comparison of means (scales with response categories from 'I strongly disagree' = 1 to 'strongly agree' = 4) from two points of measurement: Results of one-sample t-tests (t-values, degrees of freedom, p-values, effect sizes d). For comparing results of two points of measurement, data from the surveys in 2000 (N = 557 teachers) and in 2002 (N = 527) have been aggregated on school level.

	2000		2002					
Scale (number of items)	M	SD	M	SD	t	df	P	D
Teachers' appreciation of cooperation								
Effective cooperation (7)	3.14	0.51	3.29	0.45	- 2.81	108	<.01	0.27
Gain through cooperation (3)	3.16	0.48	3.32	0.49	- 3.11	107	<.01	0.30
Unhampered cooperation (3)	3.54	0.39	3.62	0.29	- 2.24	106	<.05	0.22
Teachers' contentedness with programme								
Appreciation of cooperative quality development (4)	3.49	0.33	3.63	0.31	- 4.77	110	<.01	0.45
Positive impulses for future classroom instruction (3)	2.61	0.51	2.87	0.50	- 4.68	108	<.01	0.45
No additional work load through programme activities (5)	2.76	0.50	3.07	0.38	- 6.51	109	<.01	0.62
Support by coordination on different levels (4)	3.02	0.51	3.09	0.45	- 1.54	110	Ns	0.15
Teachers' perceived development throughout the programme								
Perceived development regarding own professional competencies (3)	3.21	0.45	3.42	0.36	- 5.05	110	<.01	0.48
Perceived improvement with respect to classroom instruction (3)	2.61	0.46	2.93	0.39	- 7.38	108	<.01	0.71
Approval of programme activities from colleagues and parents (3)	2.01	0.42	2.28	0.39	- 6.26	111	<.01	0.59